

DEPARTMENT OF PUBLIC HEALTH
RADIOLOGIC HEALTH BRANCH



Radioactive Materials at Landfills

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Understanding Radiation and its Effects

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Understanding Radiation and Its Effects

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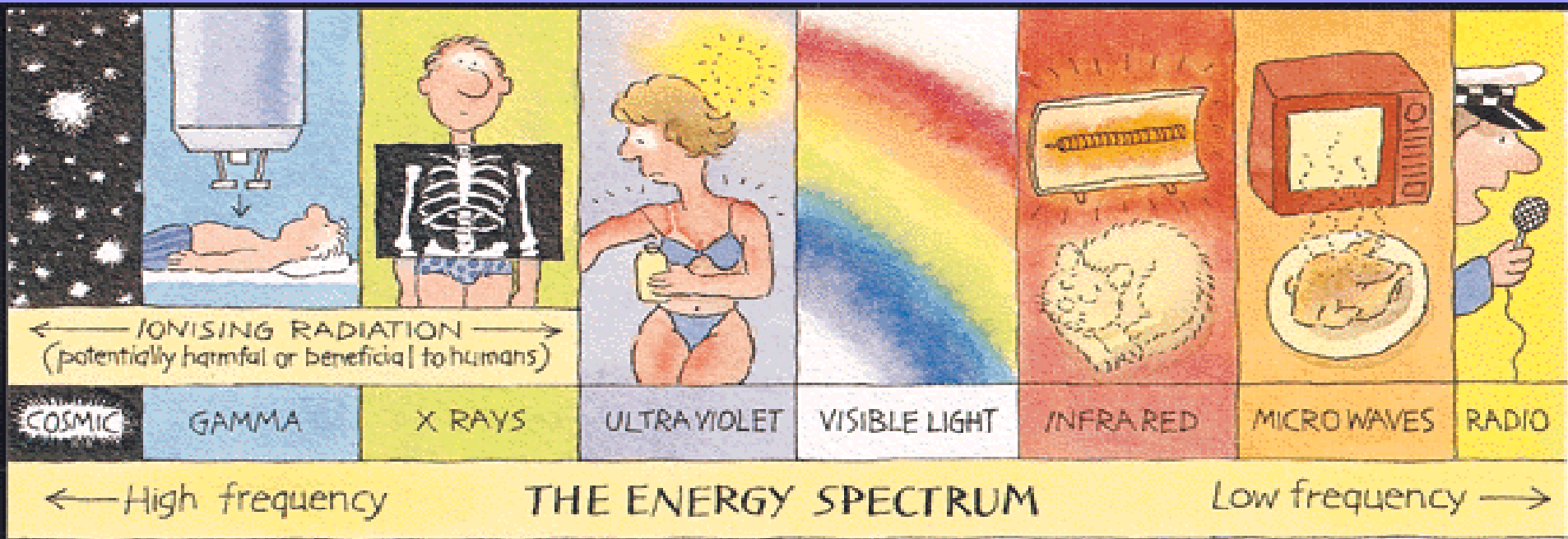
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Metric Unit Prefixes

- M = mega = 10^6 = 1,000,000
- k = kilo = 10^3 = 1000
- m = milli = 10^{-3} = 0.001
- u = micro = 10^{-6} = 0.000001
- n = nano = 10^{-9} = 0.000000001
- p = pico = 10^{-12} = 0.000000000001

Radiation is Energy

- The energy is given off by unstable (radioactive) atoms and some machines.



- For this talk, we will be focusing on ionizing radiation and its health effects.

Radiation and Radioactive Material are a Natural Part of Our Lives

- We are constantly exposed to low levels of radiation from outer space, earth, and the healing arts.
- Low levels of naturally occurring radioactive material are in our environment, the food we eat, and in many consumer products.
- Some consumer products also contain small amounts of man-made radioactive material.

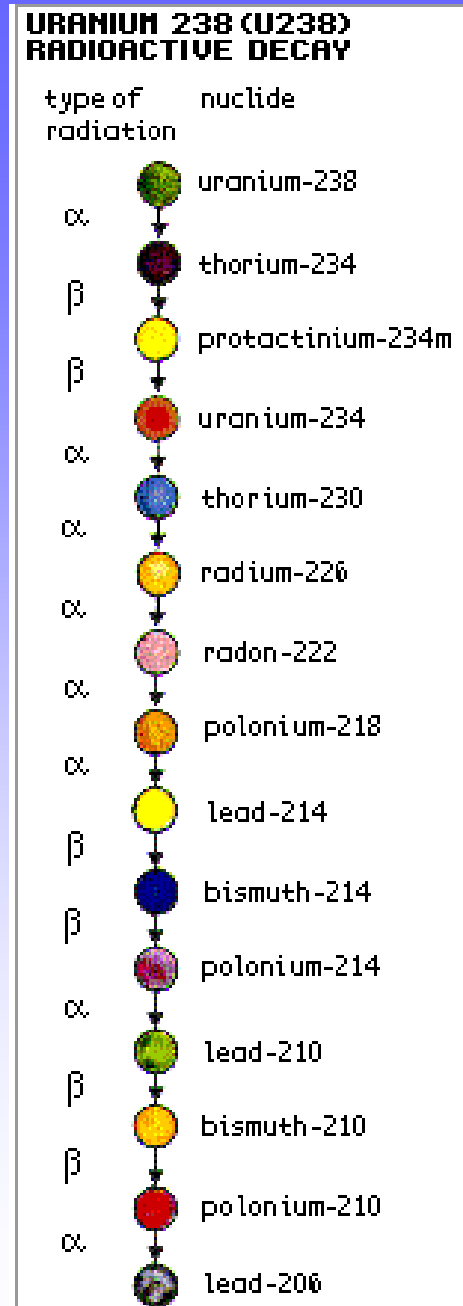


Radioactive Household Items

- Potassium chloride salt substitute (K-40)
- Smoke detector (Am-241)
- Fiestaware (uranium)
- Fertilizer (K-40, uranium)
- Lead crystal glassware (Pb-210)
- Camping lantern mantle (thorium)
- Food items (K-40) [See food handout]
- Household airborne dust (radon)

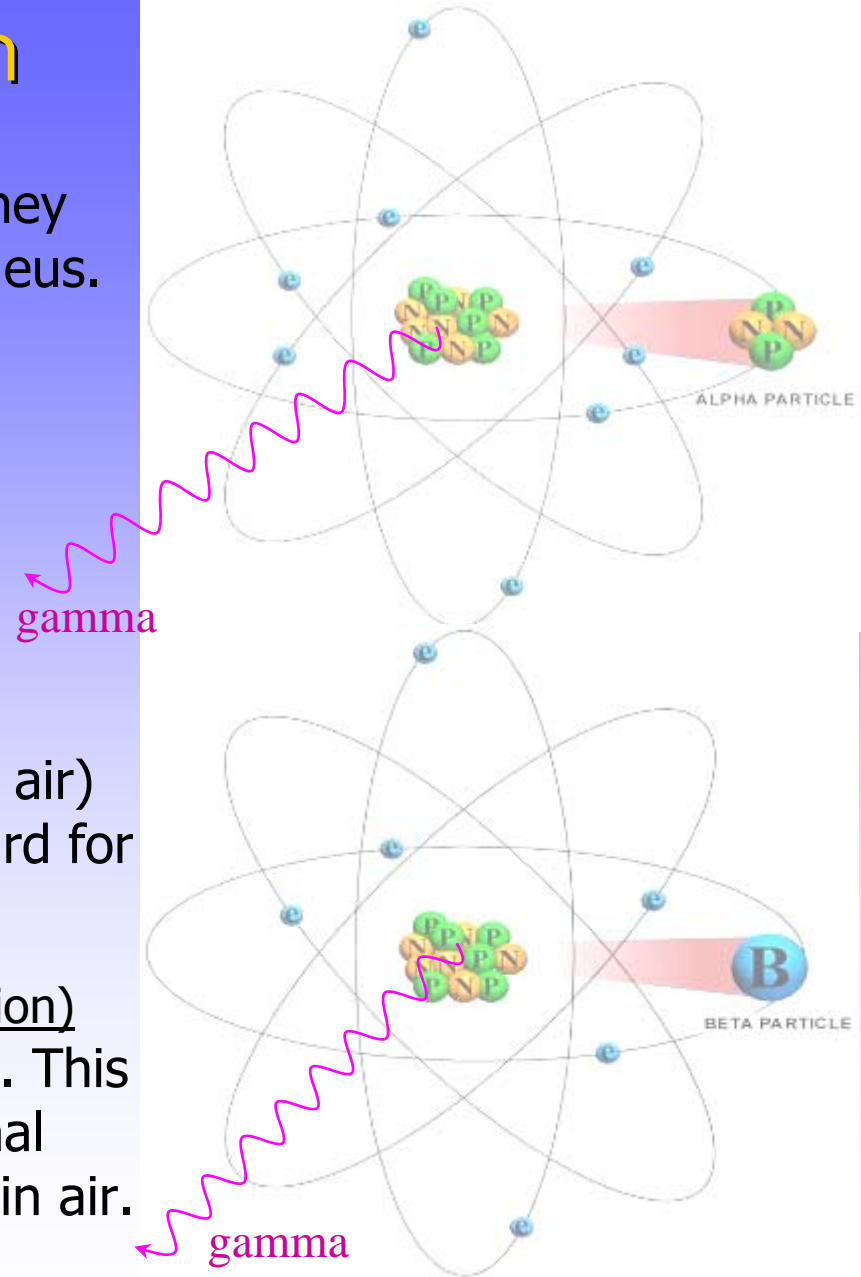
Unstable Atoms Decay

- The number of “decays” that occur per unit time in the radioactive material tell us how radioactive it is.
 - Units include curies (Ci), decays per minute (dpm), and becquerels (decays per second).
- When an unstable atom decays, it ***transforms*** into another atom and releases its excess energy in the form of radiation.
- Sometimes the new atom is also unstable, creating a “decay chain”



Forms of Radiation

- When unstable atoms transform, they often eject particles from their nucleus. The most common of these are:
 - Alpha Radiation
High energy, but **short range** (travels an inch in air, not an external hazard)
 - Beta Radiation
Longer range (10 – 20 feet in air) and can be a skin and eye hazard for high activity beta sources.
- Gamma Rays (electromagnetic radiation)
Often accompany particle radiation. This “penetrating” radiation is an external hazard and can travel 100s of feet in air.



Radioactive Decay (beta)

(Nucleus Changes – Different Element/# protons)

- ${}_1\text{H}^1$ (hydrogen): 1 proton, 0 neutrons (99.985%)
- ${}_1\text{H}^2$ (deuterium): 1 proton, 1 neutron (0.015%)
- ${}_1\text{H}^3$ (tritium): 1 proton, 2 neutrons (unstable)
- ${}_1\text{H}^3 - \text{beta} = {}_2\text{He}^3$ (stable – but usually ${}_2\text{He}^4$)
 - $T_{1/2} = 12.3$ years ($E_{\text{max}} = 18.6$ keV)
 - No gamma and/or X-ray radiation

Radioactive Decay (alpha)

(Nucleus Changes – Different Element/# protons)

- $_{84}\text{Po}^{210}$ (polonium-210): 84 proton, 126 neutrons
- $_{84}\text{Po}^{210} - \text{alpha } (_2\text{He}^4) = _{82}\text{Pb}^{206}$ (stable lead)
 - $T_{1/2} = 138.4$ days ($E = 5.305$ MeV)
 - A very small amount of gamma radiation
 - 0.0011% of time
 - 803 keV

Radioactive Decay (chain)

(Nucleus Changes – Different Element/# protons)

- ${}_{92}\text{U}^{238}$ (uranium-238): 92 proton, 146 neutrons
- ${}_{92}\text{U}^{238} - \alpha = {}_{90}\text{Th}^{234} - \beta = {}_{91}\text{Pa}^{234} - \beta = {}_{92}\text{U}^{234} - \alpha = {}_{90}\text{Th}^{230} - \alpha = {}_{88}\text{Ra}^{226} - \alpha = {}_{86}\text{Rn}^{222} - \alpha = {}_{84}\text{Po}^{218} - \alpha = {}_{82}\text{Pb}^{214} - \beta = {}_{83}\text{Bi}^{214} - \beta = {}_{84}\text{Po}^{214} - \alpha = {}_{82}\text{Pb}^{210} - \beta = {}_{83}\text{Bi}^{210} - \beta = {}_{84}\text{Po}^{210} - \alpha = {}_{82}\text{Pb}^{206}$ (stable)
- 8 alpha and 6 beta decays (various energies)
- Numerous gammas (609, 352, 295, 242, 186 + keV)

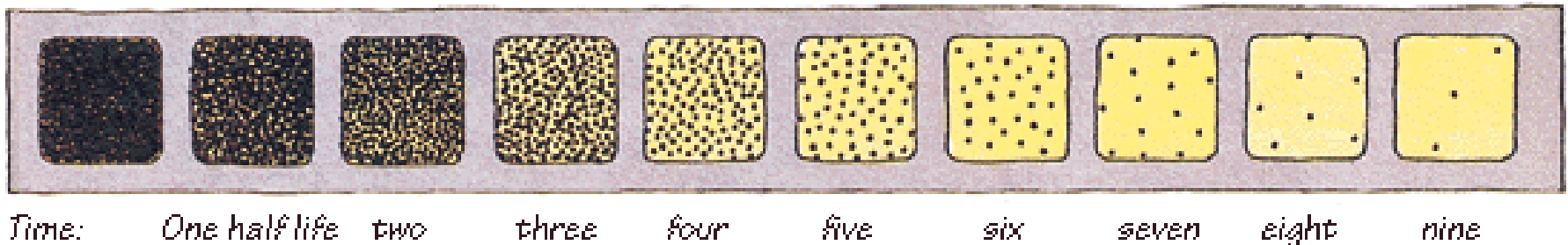
How Unstable Is It?

- The “Half-Life” describes how quickly Radioactive Material decays away with time.

It is the time required for **half** of the unstable atoms to decay.

- Some Examples:
 - Some natural isotopes (like uranium and thorium) have half-lives that are billions of years,
 - Most medical isotopes (like Technetium-99m) last only a few days

Decay rate of radioactivity: After ten half lives, the level of radiation is reduced to one thousandth



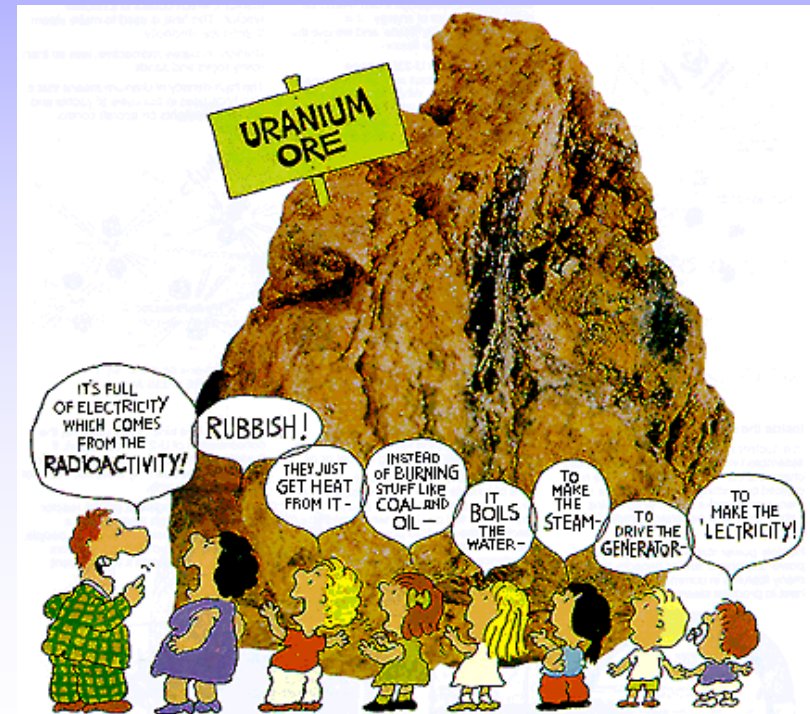
Some Isotopes & Their Half Lives

ISOTOPE	HALF-LIFE	APPLICATIONS
Uranium	billions of years	Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it's used to power nuclear reactor or nuclear weapons.
Carbon-14	5730 y	Found in nature from cosmic interactions, used to “carbon date” items and as radiolabel for detection of tumors.
Cesium-137	30.2 y	Blood irradiators, tumor treatment through external exposure. Also used for industrial radiography.
Hydrogen-3	12.3 y	Labeling biological tracers.
Irridium-192	74 d	Implants or "seeds" for treatment of cancer. Also used for industrial radiography.
Molybdenum-99	66 h	Parent for Tc-99m generator.
Technetium-99m	6 h	Brain, heart, liver (gastroenterology), lungs, bones, thyroid, and kidney imaging, regional cerebral blood flow, etc..

The Amount of Radioactivity is NOT Necessarily Related to Size

- Specific activity is the amount of radioactivity found in a gram of material.
- Radioactive material with long half-lives have low specific activity.

1 gram of Cobalt-60
has the same activity as
1800 tons of natural Uranium



What is a “Dose” of Radiation?

- When radiation's energy is deposited into our body's tissues, that is a dose of radiation.
- The more energy deposited into the body, the higher the dose.
- **Rem** is a unit of measure for radiation dose.
- Often expressed in **mrem** = **1/1000th** of a rem.
- **Rad & R** (Roentgens) are similar units that are often equated to the Rem.
- **NOTE! S.I. Units of Grays (Gy) and Sieverts (Sv) are 100 times “more powerful” (i.e. 1 Sv = 100 rem)**

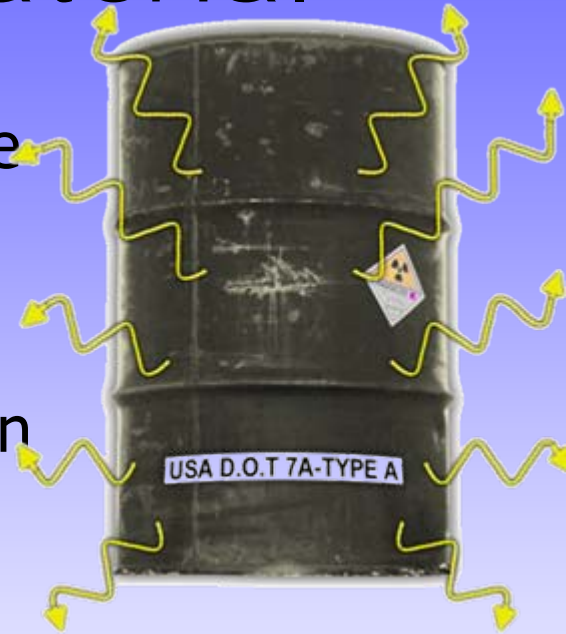
Typical Doses

Average Dose to US Public from All sources	360 mrem/year
Average Dose to US Public From Natural Sources	300 mrem/year
Average Dose to US Public From Medical Uses	53 mrem/year
Coal Burning Power Plant	0.2 mrem/year
Average dose to US Public from Weapons Fallout	< 1 mrem/year
Average Dose to US Public From Nuclear Power	< 0.1 mrem/year
Occupational Dose Limit for Radiation Workers	5,000 mrem/yr

Coast to coast Airplane roundtrip	5 mrem
Chest X ray	8 mrem
Dental X ray	10 mrem
Head/neck X ray	20 mrem
Shoe Fitting Fluoroscope (not in use now)	170 mrem
CT (head and body)	1,100 mrem
Therapeutic thyroid treatment (dose to the whole body)	7,000 mrem

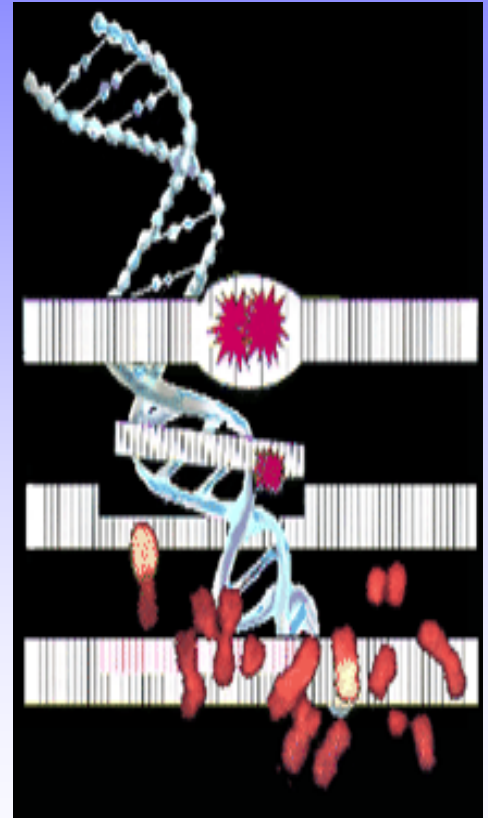
Radiation is a type of energy; Contamination is material

- Exposure to ***Radiation*** will not contaminate you or make you radioactive
- ***Contamination*** is Radioactive Material spilled someplace you don't want it.
- Radioactive contamination emits radiation
- Contact with ***Contamination*** can contaminate you with the material



Our Bodies Are Resilient

- DNA damage is most important and can lead to cell malfunction or death.
- Our body has ~ 60 trillion cells
 - Each cell takes “a hit” about every 10 seconds, resulting in tens of millions of DNA breaks per cell each year.
 - BACKGROUND RADIATION causes only a very small fraction of these breaks (~ 5 DNA breaks per cell each year).
- Our bodies have a highly efficient DNA repair mechanisms



Types of Exposure & Health Effects

- **Acute Dose**

- Large radiation dose in a short period of time
- Large doses may result in observable health effects
 - Early: Nausea & vomiting
 - Hair loss, Fatigue, & medical complications
 - Burns and wounds heal slowly
- Examples: Medical Exposures and accidental exposure to sealed sources



- **Chronic Dose**

- Radiation dose received over a long period of time
- Body more easily repairs damage from chronic doses
- Does not usually result in observable effects
- Examples: Background Radiation and Internal Deposition



Inhalation

Dividing Cells are the Most Radiosensitive

- Rapidly dividing cells are more susceptible to radiation damage.
- Examples of radiosensitive cells are;
 - Blood forming Cells
 - The intestinal lining
 - Hair follicles
 - A fetus



This is why the fetus has a exposure limit (over gestation period) of 500 mrem (or $1/10^{\text{th}}$ of the annual adult limit)

At HIGH Doses, We KNOW Radiation Causes Harm

- High Dose effects seen in:
 - Radium dial painters
 - Early radiologists
 - Atomic bomb survivors
 - Populations near Chernobyl
 - Medical treatments
 - Criticality Accidents
- In addition to radiation sickness, increased cancer rates were also evident from high level exposures.



Effects of ACUTE Exposures

Dose (Rads*)	Effects
25-50	First sign of physical effects (drop in white blood cell count)
100	Threshold for vomiting (within a few hours of exposure)
320 - 360	~ 50% die within 60 days (with minimal supportive care)
480 - 540	~50 % die within 60 days (with supportive medical care)
1,000	~ 100% die within 30 days

* For common external exposures 1 Rad ~ 1Rem = 1,000 mrem

At LOW Doses, We PRESUME Radiation Causes Harm

- No physical effects have been observed
- Although somewhat controversial, this increased risk of cancer is presumed to be proportional to the dose (no matter how small).

The Bad News: Radiation is a carcinogen and a mutagen

The Good News: Radiation is a very weak carcinogen and mutagen!

Long-term Effects of Radiation

- Radiation is assumed to increase one's risk of dying of cancer
 - The "normal" chance of dying of cancer is $\sim 23\%$ (~ 460 out of 2,000).
 - Each rem is assumed to increase that risk by 0.05% (~ 1 out of 2,000).

The occupational radiation dose limit to the whole body is 5 rem/yr

Conclusion (1 of 2):

Understanding Radiation and its Effects

- Radiation is Energy given off by Unstable Atoms and some Machines.
- Radioactive Material contains unstable atoms that give off radiation when they “decay.”
- Contamination is Radioactive Material spread someplace where you don’t want it.

Conclusion (2 of 2):

Understanding Radiation and its Effects

- Radiation damages our cell's DNA, fortunately our body has very efficient repair mechanisms.
- Large acute doses of radiation can cause sickness or even death. The severity of the effects are proportional to the dose.
- All exposures is presumed to increase the risk of cancer. The amount of "increased risk" is proportional to exposure.

Very Small DOSE = Very Small RISK

Questions Before Exam???

Exam Question

How dangerous is radioactive material?

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- How much radioactive material is present?

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- What type of radiation is present?

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How dangerous is radioactive material?

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- What type of radiation is present?
- Where is it located relative to people?
(How can people be exposed?)

Exam Question

How dangerous is radioactive material?

- How much radioactive material is present?
- What type of radiation is present?
- Where is it located relative to people?
(How can people be exposed?)
- What may change in the future?

PASS

This attests that you have successfully completed Basic Radiation and Radioactivity Training and are ready to apply your radiological knowledge in your official duties.

Radiation Monitoring Equipment

- GM Detector – Beta and/or Gamma detection
- NaI Detector – Gamma detection
- ZnS Scintillator - Alpha detection
- Dose Rate Instrument – Gamma detection
- Multichannel Analyzer – Gamma detection

[Refer to handout: Radiation in Household items]